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MML TM 93-25

**COLLOCATED TUNABLE WAVENUMBER SENSOR/ACTUATORS  
FOR SMART STRUCTURES**

N00014-92-C-0214

CDRL A001.14

Covering the period: 1 November to 30 November 1993

Submitted to:

Office of Naval Research  
Scientific Officer  
Code : 1221

Submitted by:

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## **Contract progress and activities since CDRL A001.13.**

### **Summary of progress**

- The third actuator module is currently in burnout. The volume fraction of binder/plasticiser in the tape was reduced from 43% to 41% and the tape still laminated well. Decreasing the binder content decreases the chance of flaws appearing during burnout. The burnout schedule has also been extended. The schedule is:

- 1°C/hour to 160°C	hold for 5 hours
2°C/hour to 200°C	hold for 5 hours
2°C/hour to 220°C	hold for 5 hours
2°C/hour to 280°C	hold for 5 hours
2°C/hour to 370°C	hold for 5 hours
2°C/hour to 600°C	hold for 5 hours
-20°C/hour to ambient temp.	

It is felt that with these modifications and planned changes in the sintering schedule this actuator module should be acceptable.

- The smaller actuators are being tested
  - there is still some uncertainty in the modulus measurements on the smaller actuators although this has improved considerably. Current results indicate a modulus of 15 Mpsi ( $\pm 10\%$ ). This has been achieved by machining the actuators to a parallelism <0.5 mil and mounting the actuator with a shim and epoxy glue to take up any mismatch between the testing machine pistons and the actuator faces.

### **Telephone calls, trips, and significant results**

- Bridger visited Rutgers University and gave a seminar on industrial applications of electronic ceramics. While there he discussed the measurement issue with Dr. Steven Danforth.
- Bridger and Jones attended the Quarterly Review and presented the latest results. A discussion was had with Manfred Kahn (NRL) regarding burnout and he requested some samples. Some small actuators have been held back from the last casting and we will send them to NRL upon receiving ONR Scientific Officer's permission.
- The results presented at the review intrigued the workers from Penn. State and they contacted Bridger requesting more information and samples. Of particular interest is the variation of  $T_{max}$  with sintering temperature

### **Results bearing on prior problem areas**

- No prior problem areas.

### **Programmatic changes**

- None

### **Technical or scheduling problem areas**

- The uncertainty due to bending in the measurement of the actuator modulus is beginning to be a problem area -- especially since the actuators will likely be required to operate under similar conditions to the test set up.
- The rate of spending is much lower than planned due to the sequential nature and long burnout times associated with each iteration. Once the first actuator module has successfully passed through burnout and sintering then the work will accelerate because we will fabricate the remaining actuator modules in parallel.

### **Contract and cost schedule status**

- Expended funds as of 28 November 1993, including expenditures prior to 23 July, were \$182K against a current budget of \$265K.
  - A cost schedule, reflecting the 23 July program restart, is attached.

## **Plans for December 1993**

- Electromechanical measurements will continue on the first set of small actuators.
  - Electromechanical modelling on the actuators testing the effects of the margin around the hole and a transition layer will be conducted.
  - The next actuator module iteration will complete burnout and be sintered. A fourth iteration will be started.
  - The first large-scale burnout experiment will be completed and the results analyzed. We will add temperature monitors in various parts of the actuator for the second experiment.

## **Preparers**

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**SCHEDULE, MILESTONES, AND DELIVERABLES -- Updated December 1, 1993**

<b>Phase I</b>	1993						1994					
	J	A	S	O	N	D	J	F	M	A	M	J
<b>CONTRACT START</b>	◆											
<b>Task 1: Materials Preparation and Device Design</b>												
• Purchase additional starting materials	▲											
• Formulate ceramic materials	█	█	█	█	█	█						
• Materials characterization	█	█	█	█	█	█						
• Model	█	█	█	█	█	█	█	█	█	█	█	█
<b>Task 2: Module Fabrication</b>												
• Prepare multilayer devices	█	█	█	█	█	█	█	█	█	█	█	█
• Burnout, isopress, and fire devices	█	█	█	█	█	█	█	█	█	█	█	█
• Polish and terminate devices	█	█	█	█	█	█	█	█	█	█	█	█
<b>Task 3: Device Testing</b>												
• Initial electrical characterization	█	█	█	█	█	█	█	█	█	█	█	█
• Initial mechanical characterization	█	█	█	█	█	█	█	█	█	█	█	█
• Force/displacement versus field and prestress	█	█	█	█	█	█	█	█	█	█	█	█
• Strain versus field	█	█	█	█	█	█	█	█	█	█	█	█
• (Hipotting)	█	█	█	█	█	█	█	█	█	█	█	█
• Reliability testing (extended cycling)	█	█	█	█	█	█	█	█	█	█	█	█
• Final "proof" characterization	█	█	█	█	█	█	█	█	█	█	█	█
<b>DELIVERABLES</b>												
<b>REPORT</b>												
	J	A	S	O	N	D	J	F	M	A	M	J

**KEY:**

Milestone:



Planned task:



Completed task:



Task with new projected completion:



ONR Sch Miles Deliv Ph-I

Dec 6, 1993

## EXPENDITURE CHART

3117-000 ONR  
Co-Fired High-Force Actuators

